Using Ground-based Radar to Detect Changes in the Didymos Binary Orbit

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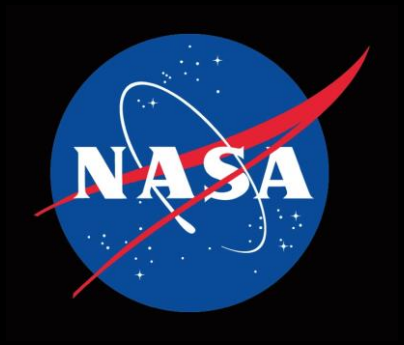
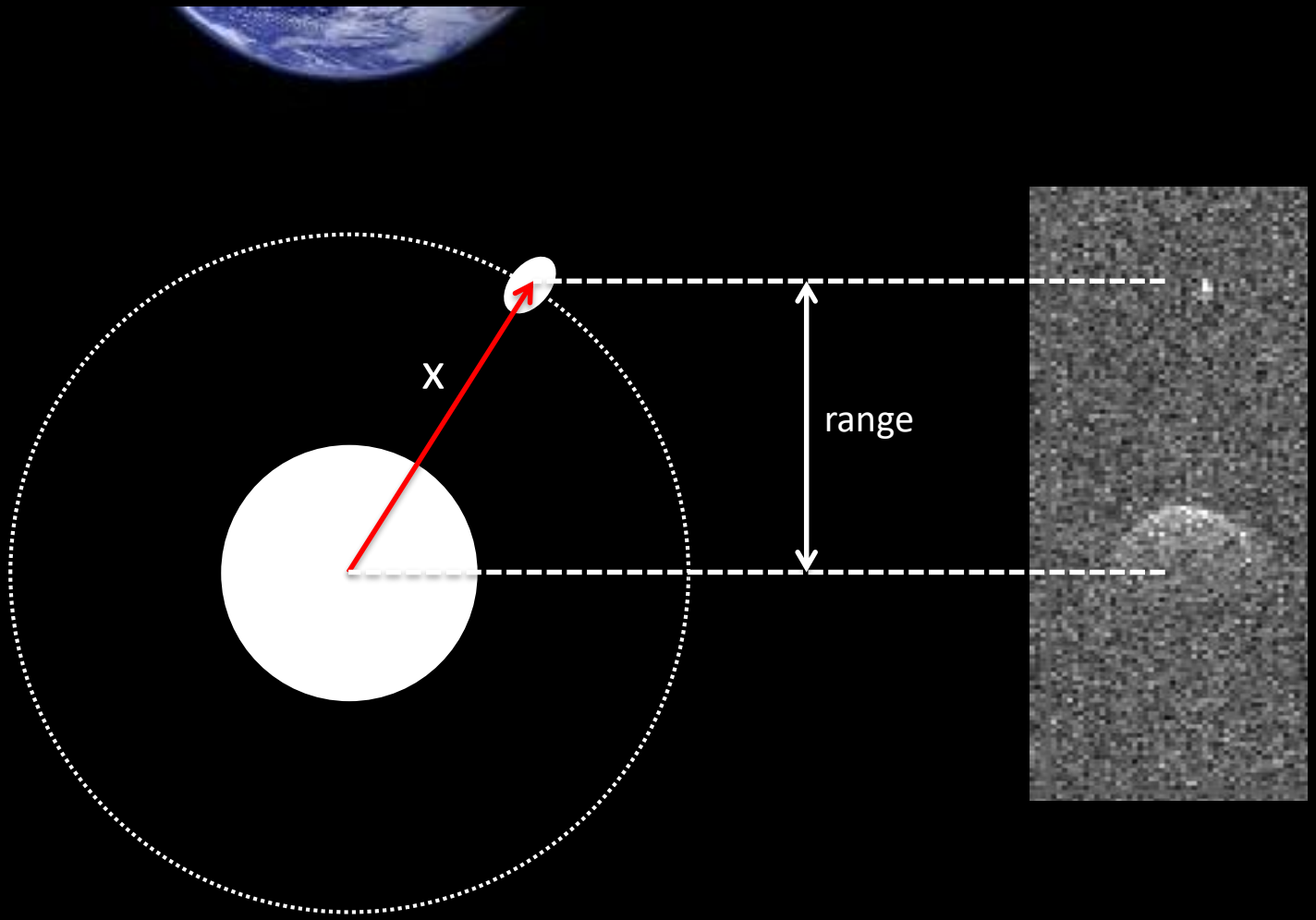


Requirements

- Precise knowledge of the mutual orbit just prior to impact. Assuming an orbital period change of 7 minutes due to the impact, we would need to know:
  - The orbit pole to within about 10 degrees (already satisfied)
  - The orbital period to within about 0.005 hours
  - The orbital position of the satellite to within about 5 degrees
- Detection of the secondary in delay-Doppler images and/or echo power spectra

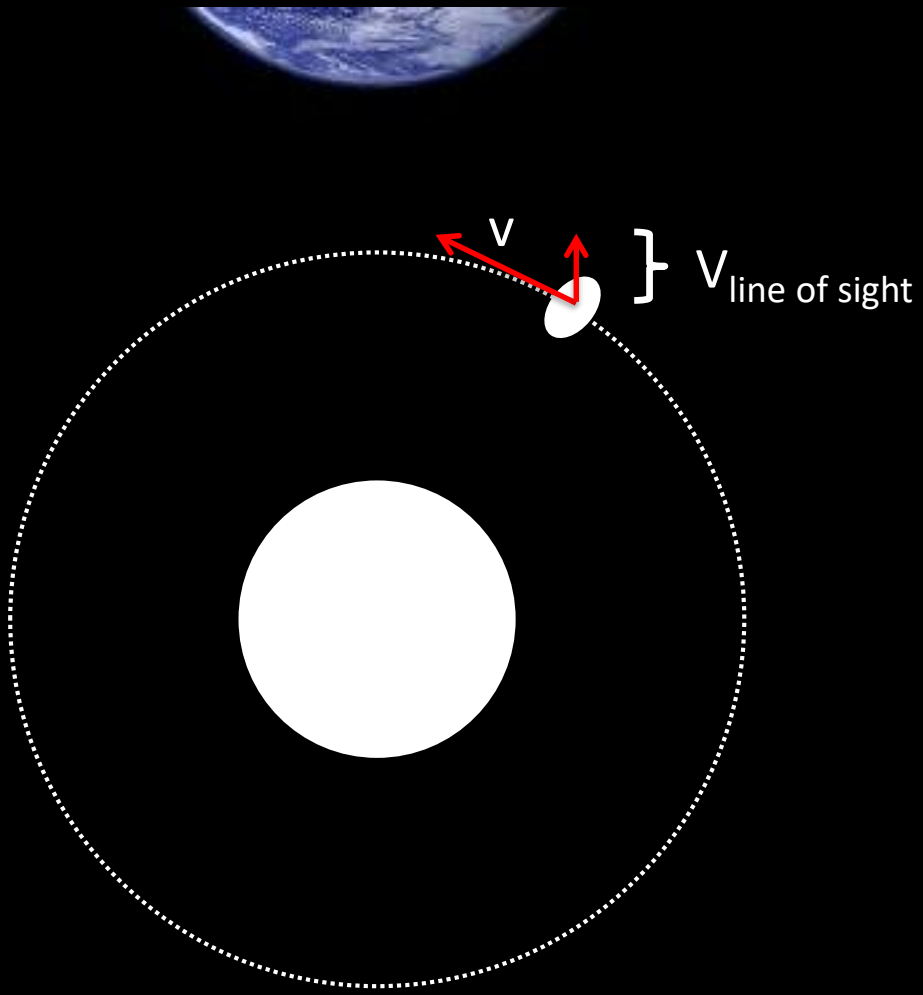
Radar observables



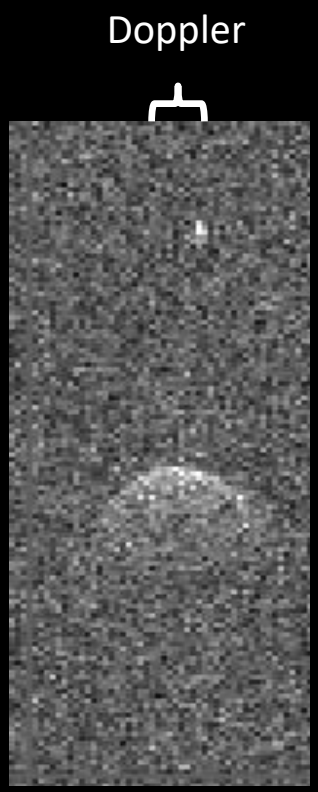
Pole-on view of a binary system

Radar delay-Doppler image

Radar observables



Pole-on view of a binary system



Radar delay-Doppler image

Predicted radar SNRs for the satellite

Goldstone

UTC date	dist (au)	SNR/ day	SNR/ run
2022 Sep 25	0.078	6	1
2022 Sep 26	0.076	9	1
2022 Sep 27	0.075	11	2
2022 Sep 28	0.074	12	2
2022 Sep 29	0.073	14	2
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2022 Oct 14	0.078	19	2
2022 Oct 15	0.080	18	2
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2022 Oct 21	0.090	12	1
2022 Oct 22	0.092	11	1
2022 Oct 23	0.094	10	1
2022 Oct 24	0.095	9	1

Arecibo

UTC date	dist (au)	SNR/ day	SNR/ run
2022 Oct 24	0.095	44	13
2022 Oct 25	0.097	55	13
2022 Oct 26	0.099	61	14
2022 Oct 27	0.101	64	14
2022 Oct 28	0.103	65	14
2022 Oct 29	0.105	65	13
2022 Oct 30	0.107	63	12
2022 Oct 31	0.110	60	12
2022 Nov 01	0.112	58	11
2022 Nov 02	0.114	55	10
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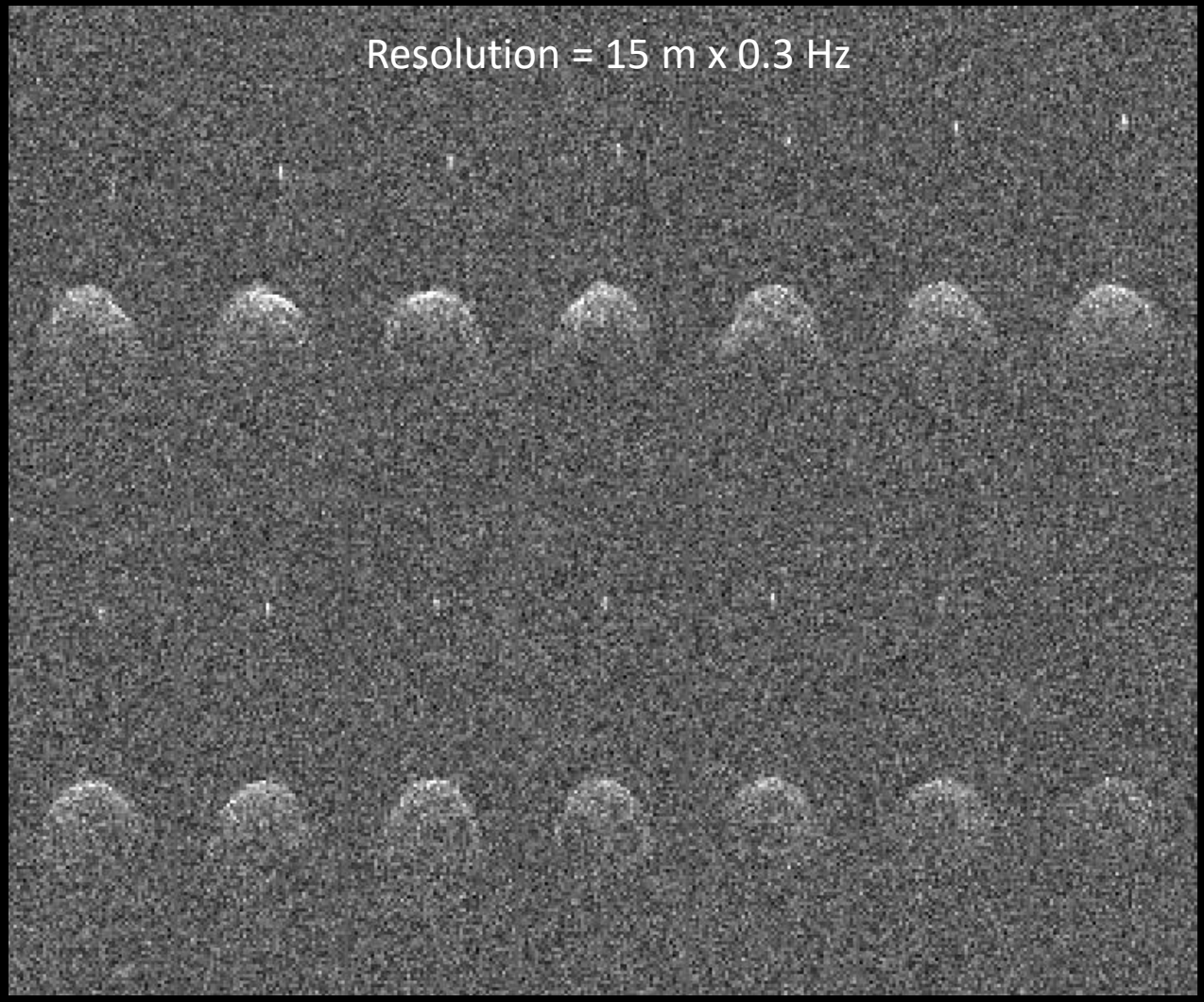
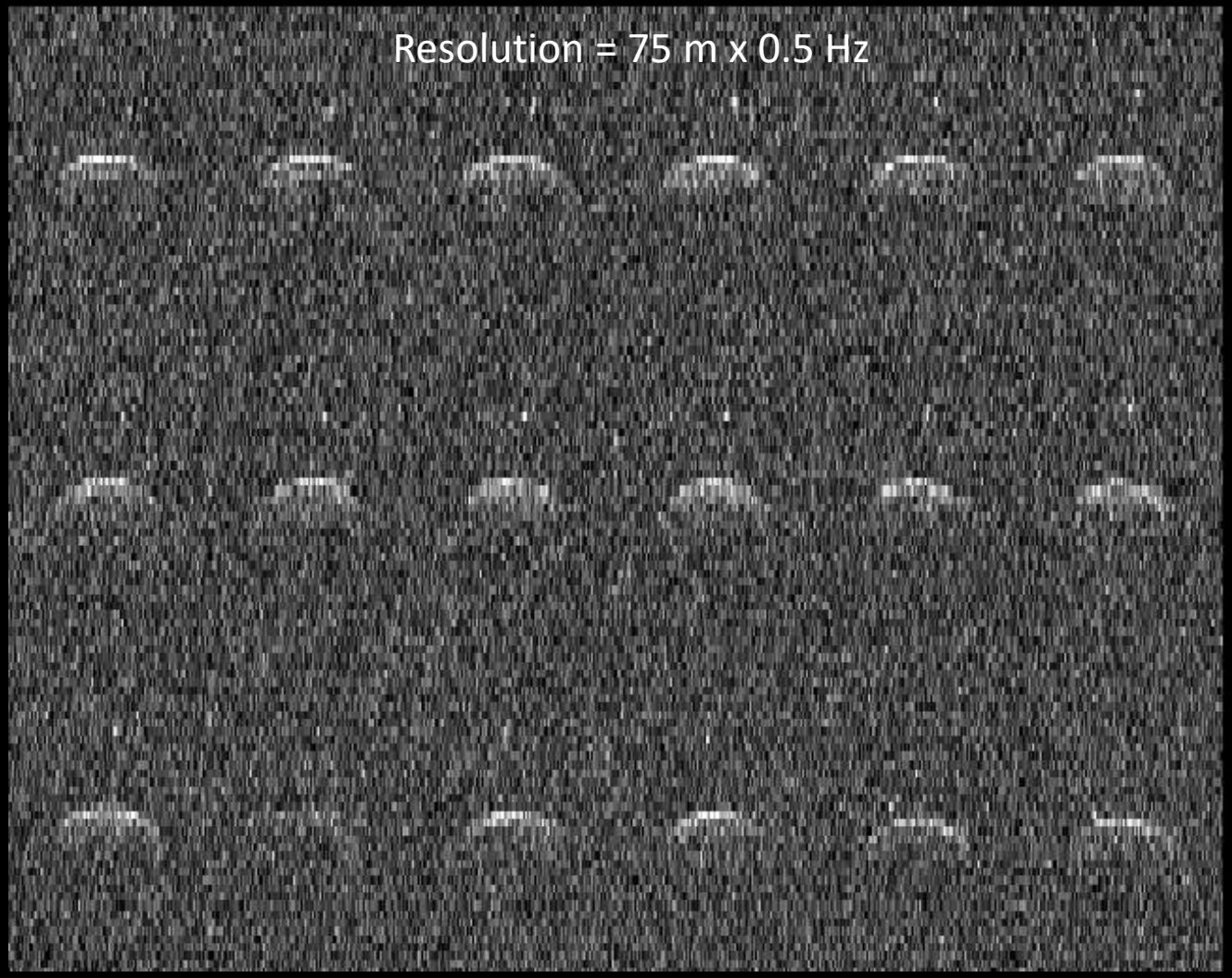
2022 Dec 04	0.181	10	2
2022 Dec 05	0.183	10	2
2022 Dec 06	0.185	9	2

Arecibo Images from 2003 Nov 24



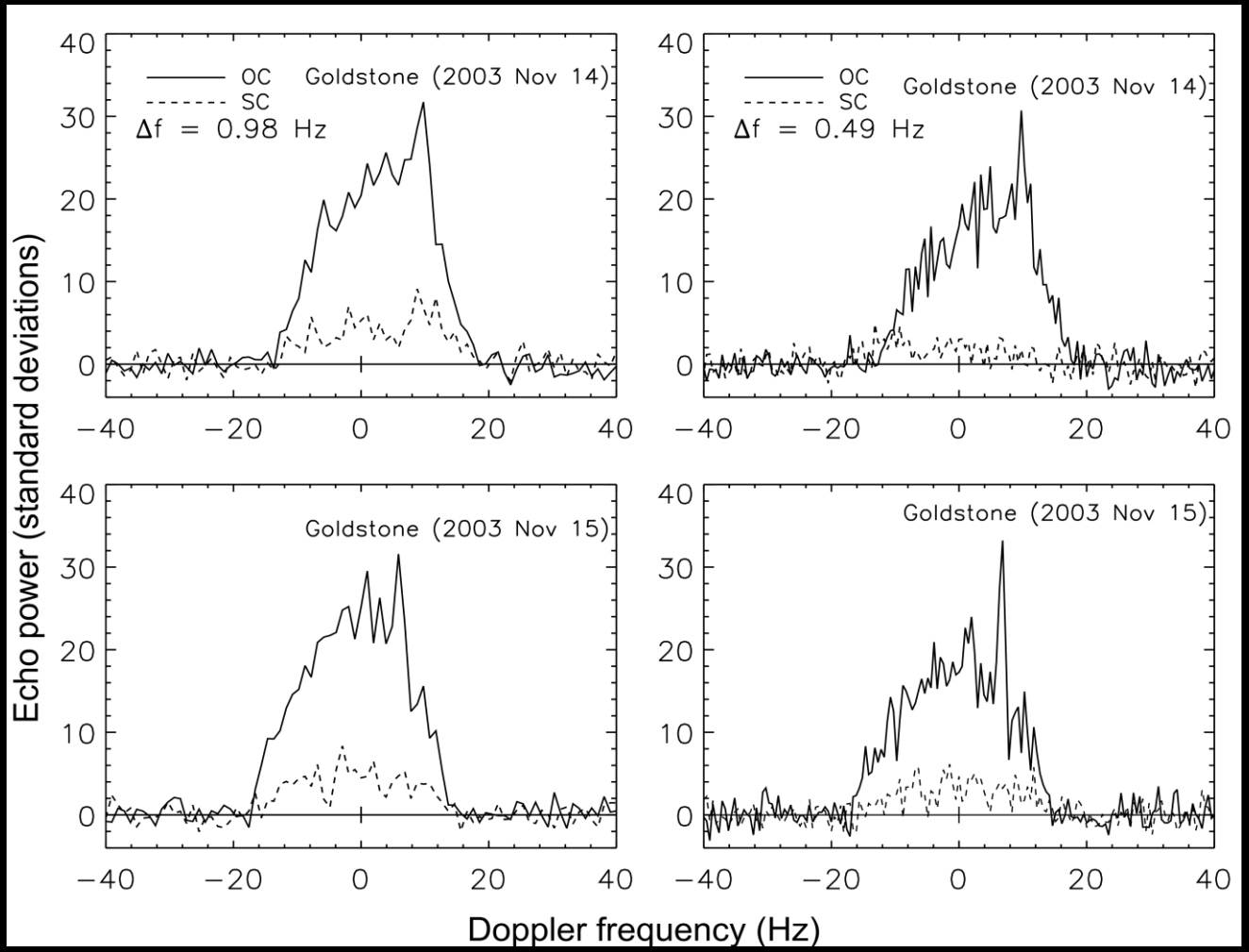
The strongest Arecibo SNRs in 2022 will be 1/6th of those shown here

Goldstone Images from 2003 Nov 15

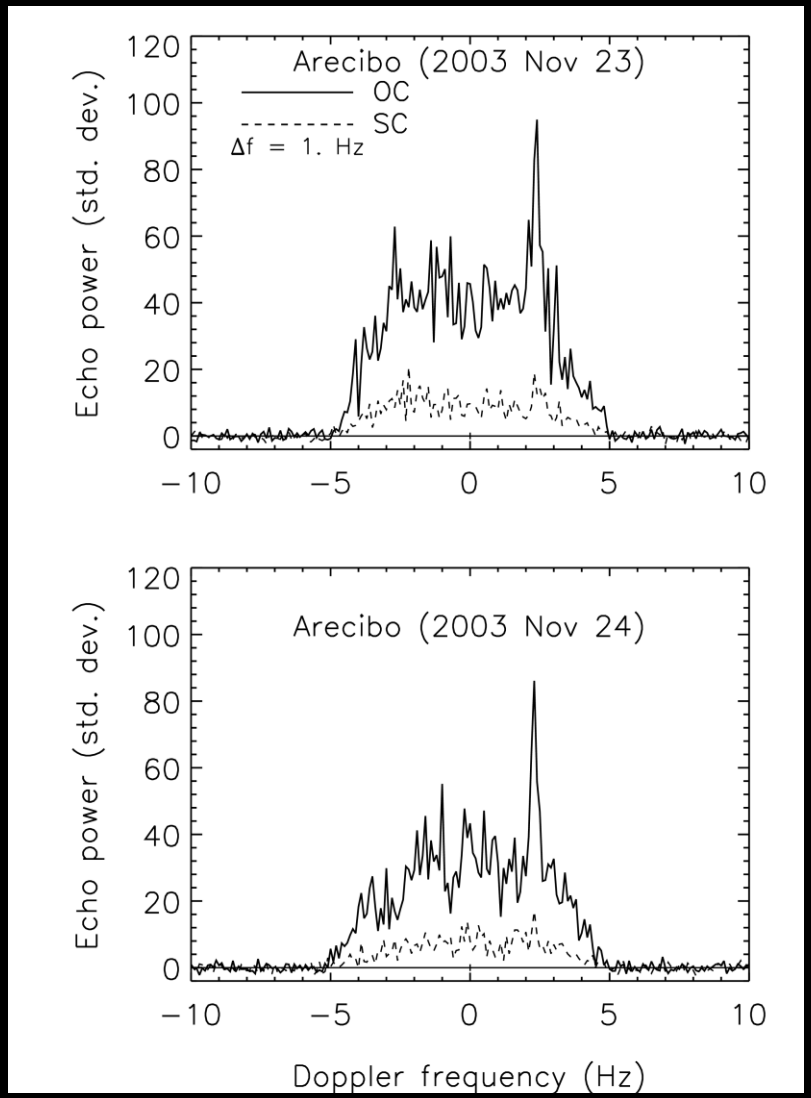


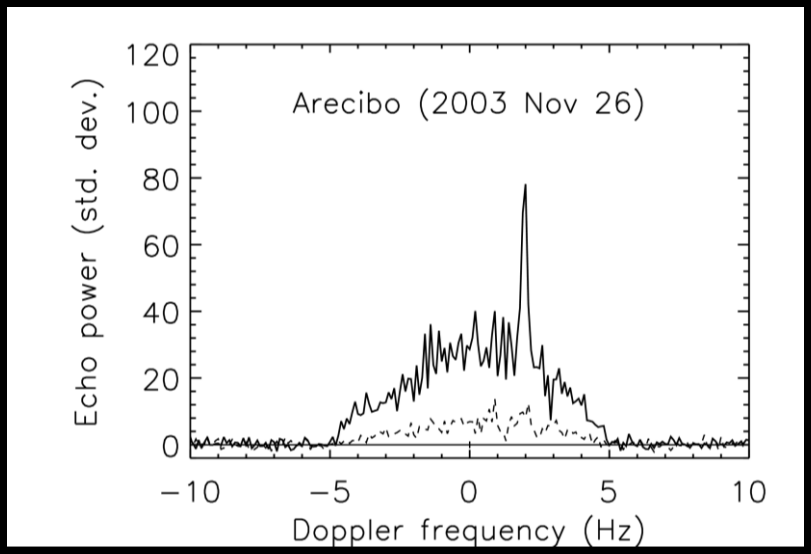
The highest Arecibo SNRs in 2022 will be 1.6x stronger than in these images

2003 Goldstone echo power spectra

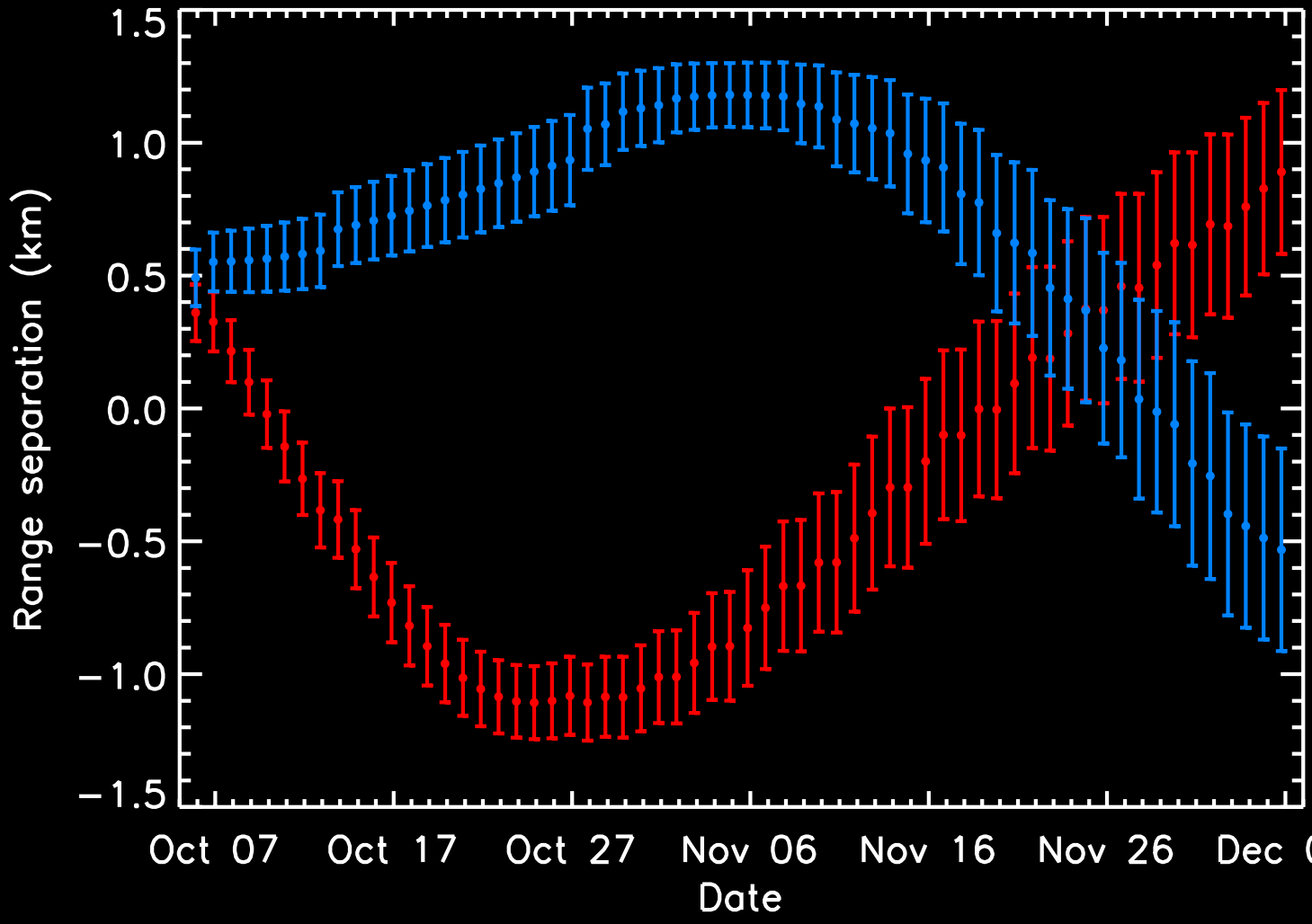


2003 Arecibo echo power spectra



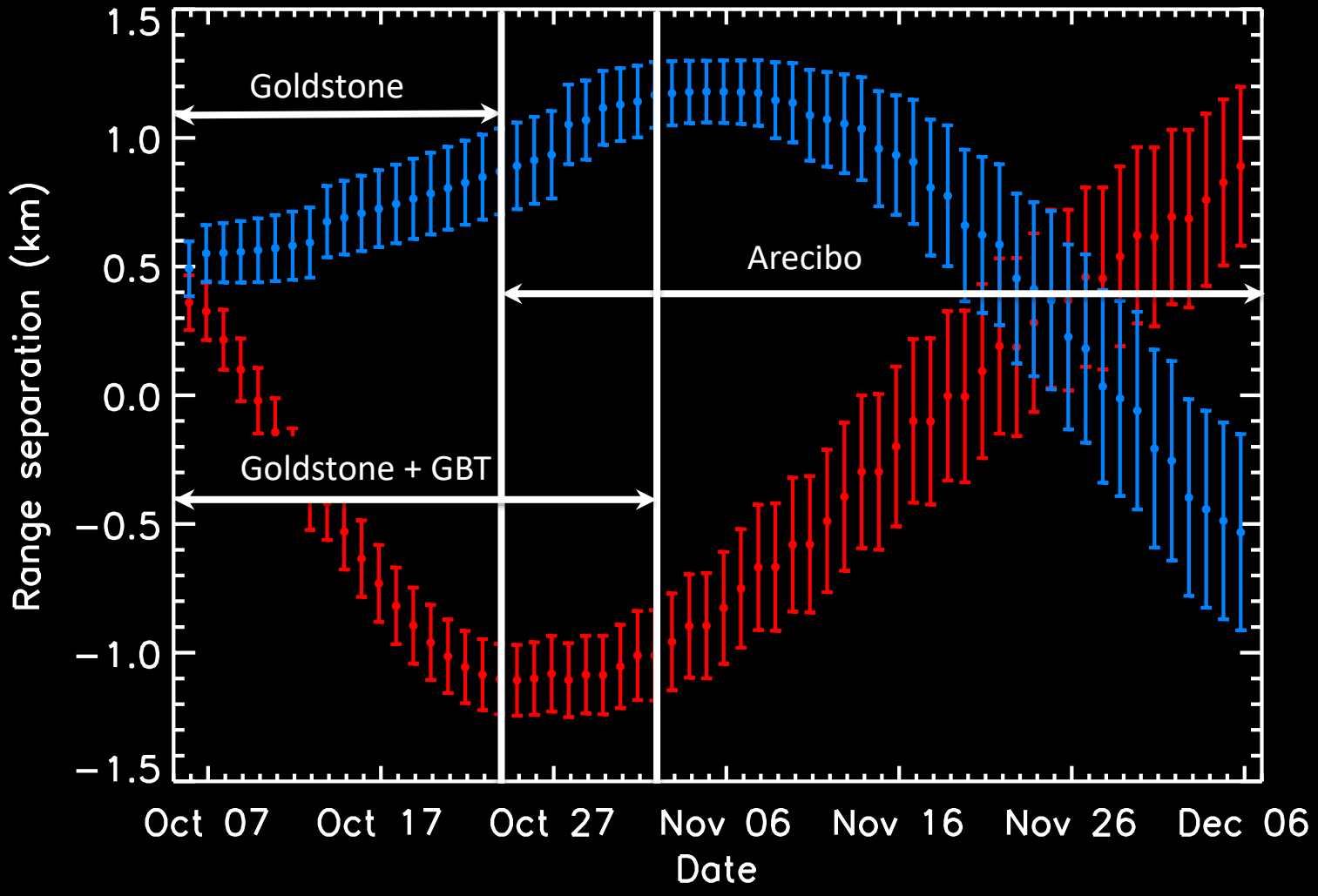


Range displacement predictions

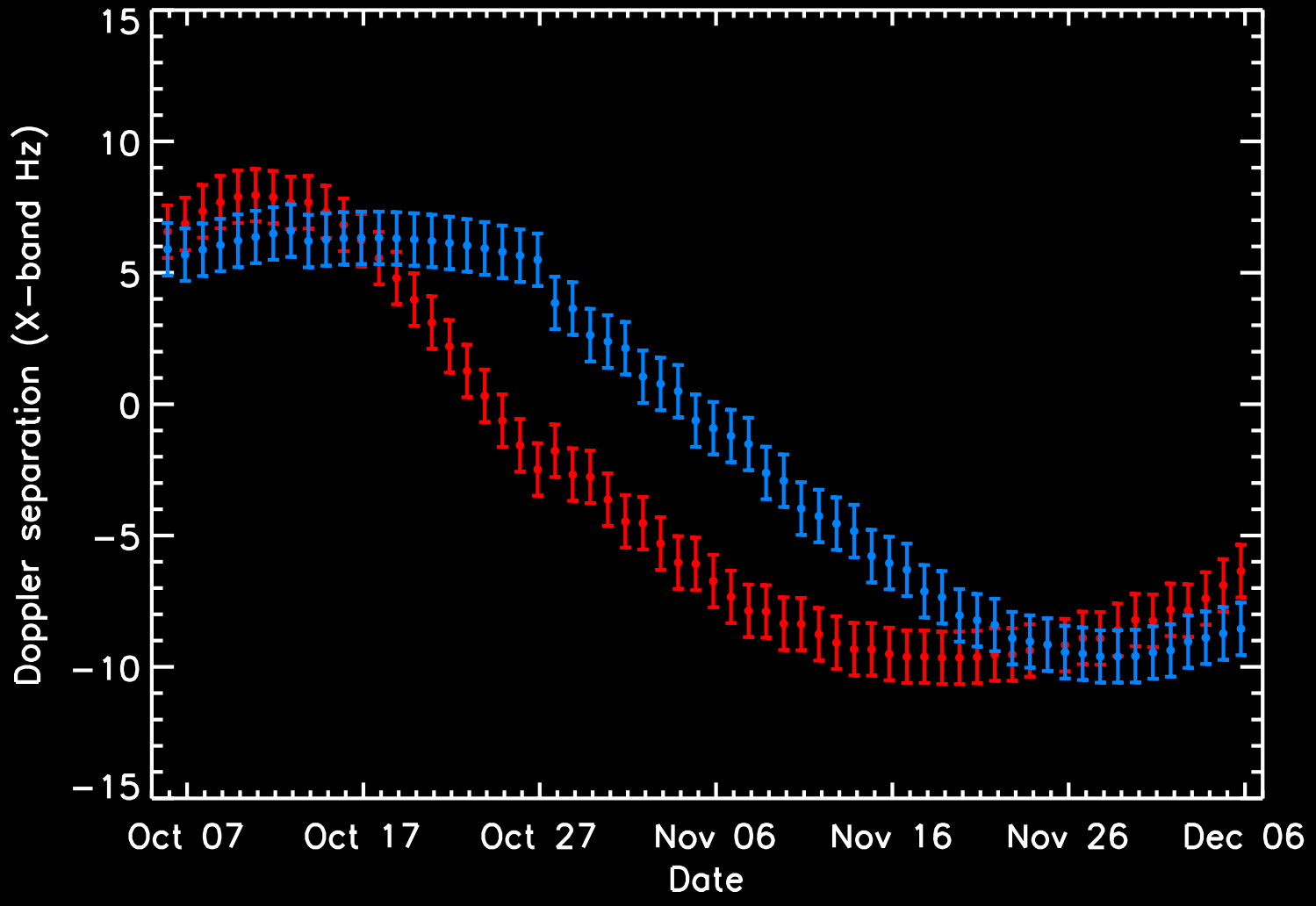


Red and blue points indicate modeled range separation measurements for the unperturbed and perturbed orbits respectively. Error bars include orbital and measurement uncertainties

Range displacement predictions

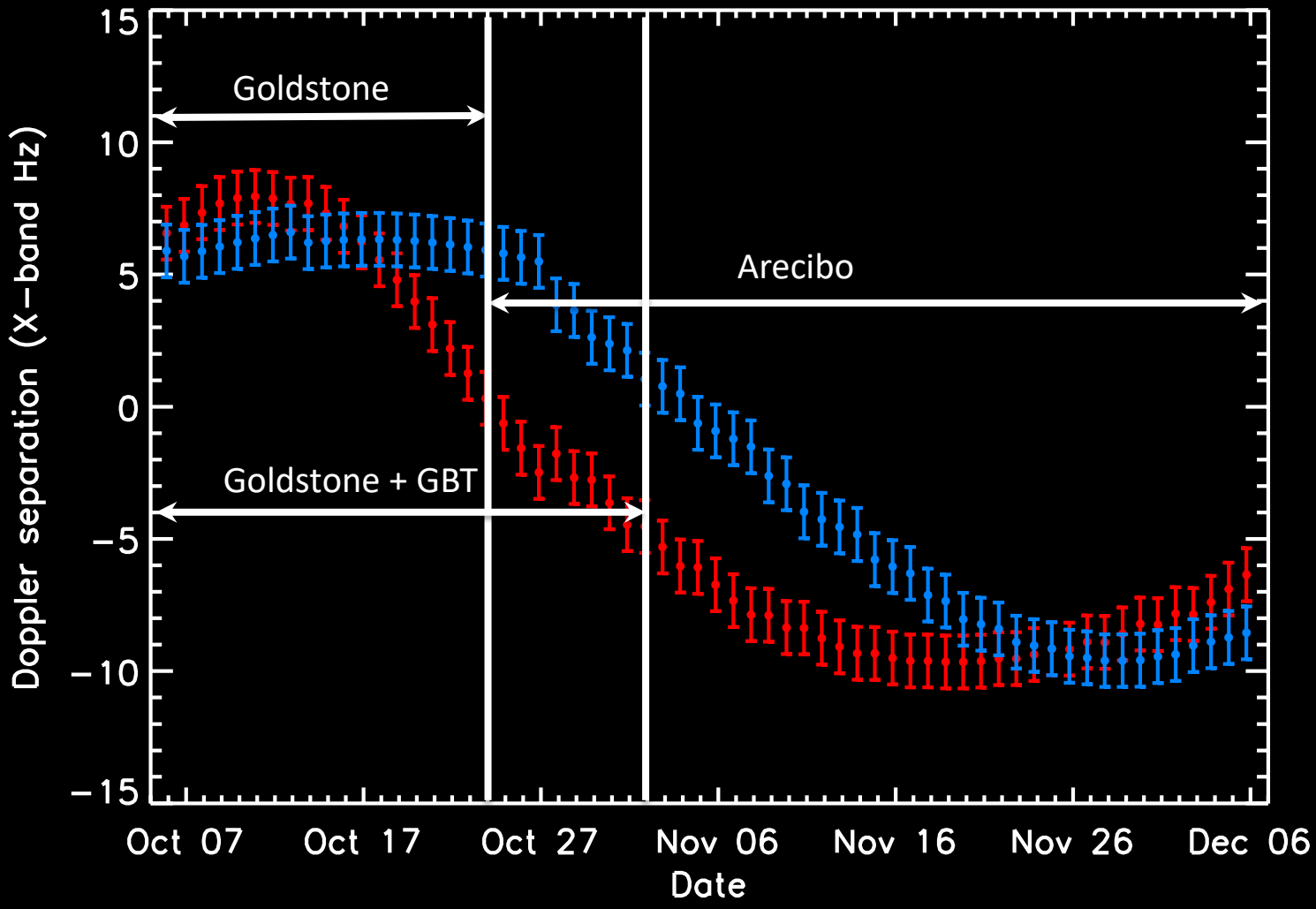


Doppler displacement predictions



Red and blue points indicate modeled Doppler separation measurements for the unperturbed and perturbed orbits respectively. Error bars include orbital and measurement uncertainties

Doppler displacement predictions



Conclusions

- Arecibo signal-to-noise ratios in 2022 will be a factor of six lower than in 2003 but still strong enough for imaging.
  - Arecibo SNRs will still be about 60% higher than SNRs at Goldstone in 2003.
- The secondary will be detectable at Arecibo in delay-Doppler for about 2 weeks (Oct 24 to Nov 06) with SNRs comparable to those at Goldstone in 2003.
- Goldstone SNRs will be $1/4^{th}$ of the values in 2003.
- If we transmit at Goldstone and receive at Green Bank, SNRs increase by 2.3 and the detectability of the satellite lengthens by about one week.
- Detection of the secondary in delay-Doppler images using Goldstone and Green Bank is likely for about 1 week before and after the planned DART impact date of Oct 5.
  - The predicted 7 minute orbit change should be detectable at Goldstone/Green Bank even in echo power spectra.